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Circular Bioeconomy and Sustainable Food Systems Across Africa: Impacts, Challenges, and Possibilities

Tom Tabler, Professor and Extension Poultry Specialist, Department of Animal Science, University of Tennessee Institute of Agriculture
Thomas Odiwuor Rewe, Associate Professor of Integrated Agro-Systems, Pwani University, Kilifi, Kenya
Joseph Felix Chibanga, Scientific Officer-Animal Nutrition, Animal Science Research Centre, National Institute for Scientific and Industrial Research, Lusaka, Zambia
Tanner Thornton, Graduate Research Assistant, Department of Animal Science, University of Tennessee Institute of Agriculture
Logan Lewis, Extension Agent I, University of Tennessee Extension, Montgomery County
Pramir Maharjan, Research Assistant Professor and Extension Specialist, Department of Poultry Science, Texas A&M University

A circular bioeconomy is an economy powered by nature. It is an economic framework that combines the principles of the circular economy and the bioeconomy to use renewable biological resources (plants and organic waste) as raw materials for products, energy and materials, keeping these resources in a closed-loop system to reduce waste and reliance on fossil fuels. It is a new economic model that emphasizes the use of renewable natural capital and focuses on minimizing waste. Sustainable food systems involve a holistic approach to providing food security and nutrition to all people without compromising the economic, social and environmental foundations for future generations. By raising awareness about waste reduction, management and valorization, alongside incentivizing circular bioeconomy practices, the food system can evolve into a more sustainable and closed-loop model, contributing to a more resilient future across Africa.

Africa's bioeconomy presents a unique opportunity to simultaneously advance sustainable food systems, climate resilience and inclusive economic development. We look at the impacts, challenges and possibilities of the circular bioeconomy across Africa and consider how regional policy frameworks, investment mechanisms, gender and youth empowerment and digital innovation can unlock Africa's vast bioresources. By learning from global experiences while tailoring solutions to African contexts, circular bioeconomy strategies can transform agriculture, create green jobs and deliver measurable progress toward the United Nations (UN) Sustainable Development Goals (SDGs). We conclude with practical recommendations for policymakers, investors and stakeholders to accelerate Africa's bioeconomy transition.

The need for sustainable food systems requires a shift from the traditional linear model towards a circular bioeconomy. The circular bioeconomy model focuses on closing the loop within the food system by promoting regenerative agricultural practices, minimizing the generation of food waste and losses within the supply chain and encouraging the valorization of waste and by-products (Rizwan et al., 2025). There are numerous reasons, that range from the potential for improved environmental sustainability, greater food security and food safety, and improved practical business opportunities and innovations, to invest in the future of the circular bioeconomy, especially for many African countries that are still largely agrarian. Possibilities include the development of innovative food products manufactured from bioresources, the extension of product shelf life through utilizing biodegradable films and biobased compounds, and the improvement of food safety via sustainable packaging (Nguyen et al., 2025). For many developing countries, agriculture, forestry and fisheries constitute vital economic drivers and form the mainstay of livelihoods for many individuals. For more industrialized countries, land and water-based biological resources provide many of the basic materials that power their industries (Gatune et al., 2021).

Additionally, circular bioeconomy practices increase agricultural productivity by enhancing crop yields and livestock productivity (Nguyen et al., 2025). From a business perspective, they optimize resource use, boost profitability and generate new revenue streams from waste products. Socially, these practices improve stakeholder wellbeing and generate employment opportunities. Environmentally, they support natural capital regeneration, reduce ecological footprints and promote the sustainable use of resources. Despite these benefits, however, significant gaps remain, particularly regarding cross-sectoral relationships and multi-level impacts of circular bioeconomy practices (Nguyen et al., 2025).

Impacts

Due to its biological complexity, agriculture offers some of the clearest examples of circular resource use, many of which have evolved out of necessity over centuries of practice and formal and informal knowledge transfer in transitional low input and extensive farming systems. Examples include the observance of seasonality in production to match crop calendars with peak growing conditions, the use of crop residues in animal feeds, soil nutrient augmentation from livestock waste application and the optimized use of other animal bio products, including for renewable energy production (Duncan et al., 2023).

In broad terms, circular bioeconomy envisions food and agricultural systems that are coupled with material and energy flows at various levels of the value chain (production, processing, distribution, consumption). They can be reused as agricultural inputs (e.g., manure, composts or sludges as biofertilizer, treated municipal wastewater for irrigation, food waste as animal feed), used for producing other valuable products or serve as sinks for waste (e.g., sequestration of atmospheric CO2 in soils) (Basso et al., 2021).

African nations are slowly adopting bioeconomy strategies to govern biodiversity for sustainable development; addressing gaps in education, research and development; and policymaking (Aidoo, et al., 2023). Currently, however, only 12 African countries have established bioeconomy strategies: South Africa and Ethiopia have comprehensive bioeconomy strategies (Proestou et al., 2024; Bio and Emerging Technology Institute, 2024), while Ghana, Kenya, Mali, Mauritius, Mozambique, Namibia, Nigeria, Senegal, Tanzania and Uganda have bioeconomy-related strategies (Proestou et al., 2024).

In line with this, the East African countries (Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda and South Sudan) are keen to chart a new development strategy (Gatune et al., 2021). Towards this end, the countries have identified the bioeconomy as a potential pathway forward (BiSEA, 2020). The strategy is based on the belief that a successful deployment of the bioeconomy has the potential to promote sustainable, bio-based economic growth, new employment opportunities, improved livelihoods, food security and wealth creation (Gatune et al., 2021). Europe has been especially keen on developing the bioeconomy sector. It sees the bioeconomy as key to ensuring food security, creating jobs and ensuring European competitiveness, sustainable management of natural resources, reducing dependence on non-renewable resources, and mitigating and adapting to climate change (European Commission, 2012). The FAO (2019a) indicates that over 50 countries have developed a bioeconomy strategy.

The effects of climate change on food production and security are numerous and varied and represent one of the greatest challenges facing humanity today. As the human population increases, there is increasing pressure on land availability and water resources. Yet, regarding many staple crops, warming temperatures have caused decreases in overall yields, while at the same time, the demand for cheaper and more sustainable food continues to increase. Climate change has adverse impacts on food systems at different levels, including ocean acidification, water scarcity, drought, soil degradation, pest resistance, disease pressures, crop-yield variability and loss of biodiversity (Kanaujia et al., 2025).

The increasing concern about changing climatic conditions and their effects on the management and conservation of biological resources highlights the urgent need to develop effective models for sustainable resource management (Mougenot and Doussoulin, 2022). The bioeconomy is the production, utilization, and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes, and services across all economic sectors, aiming toward a sustainable economy (Global Bioeconomy Summit, 2018).

Since the first industrial revolution, we have seen tremendous improvement in livelihoods for many countries, especially industrialized countries (Rifkin, 2013). However, the economies of these industrialized countries are now based on the exploitation of minerals and fossil fuels, which come with a cost. Mineral resources and fossil fuels are not renewable, and current consumption jeopardizes future availability. The current linear economies as structured have created significant pollution and released tremendous amounts of greenhouse gases (GHGs) that are adding to climate change and threatening the environment (Gatune et al., 2021). As a result, we are now seeing efforts to reduce the environmental footprint of current economic activities, ranging from urging a shift towards more sustainable production and consumption patterns to an outright call for rethinking the entire economic structure to make it sustainable and yet still able to support high living standards (Gatune et al., 2021).

In Sub-Saharan Africa (SSA), agricultural activities contribute significant amounts of GHGs emitted to the environment, leading to climate change and global warming. Despite some reduction in GHG emissions, the contribution of emissions is still high particularly among small-scale farmers that practice mixed crop/livestock farming in SSA. For example, in Zambia, poor quality early maturing and lignifying indigenous grasses, an extensive system of cattle production (leading to uncontrolled dropping of manure on pastures), and tropical environmental conditions, has resulted in significant GHG emissions. According to the International Centre for Tropical Agriculture (CIAT) and the World Bank (2017), burning savanna and agricultural soils are significant contributors to emissions, and more contributions come from enteric fermentation as well as manure left on pasture and manure management practices (Fig. 1).

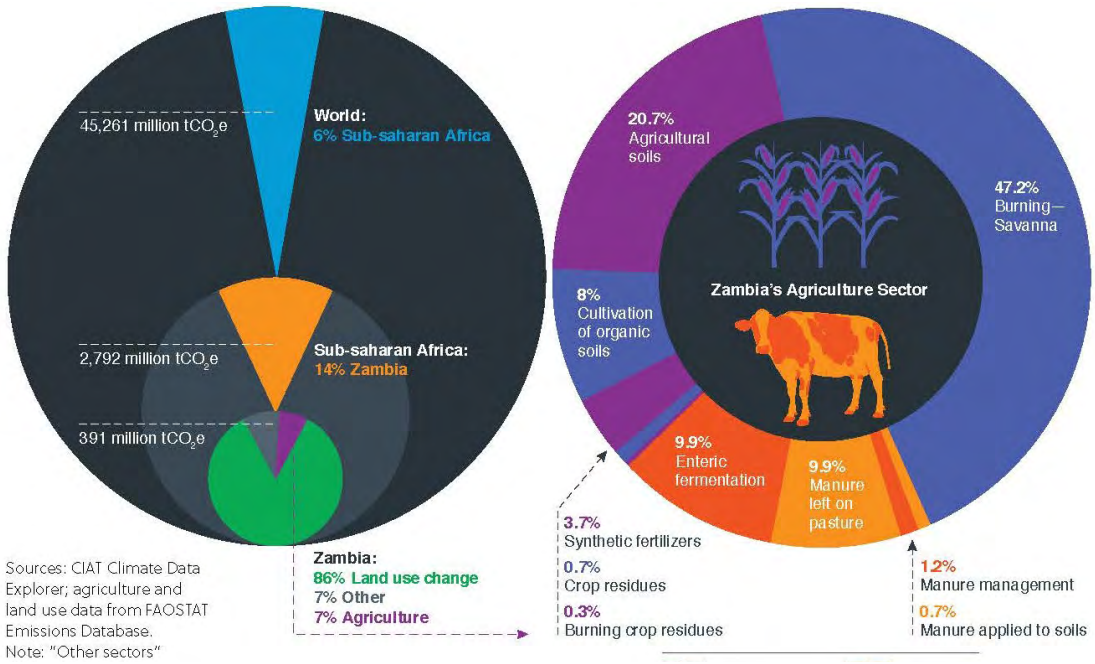

Figure 1: *GHG emissions: Zambia's agriculture sector in perspective. Source: World Bank, 2019.*

Global warming has led to observed changes in the climate across Africa, with notable increases in mean temperature and more frequent heatwaves, whereas trends in rainfall vary across regions (Trisos et al., 2022). Increased heat stress has direct effects on the productivity of crops and livestock, but it also affects agricultural labor, provided by both people and draught animals (Kjellstrom et al., 2016), leading to indirect effects on agricultural productivity (Descheemaeker et al., 2025). Increased temperatures lead to accelerated crop development and changes in the photosynthesis process. This could have a positive or negative impact depending on the crop and the base temperature.

Animals are somewhat better adapted to dry and variable climates than crops, yet they are also directly impacted by climate change as increased temperatures affect physiology, fertility, feed intake and susceptibility to diseases, with repercussions on overall productivity (Godde et al., 2021). Increased temperatures are a particular threat to modern poultry genetics with exceptional performance potential under the right weather conditions and management practices. However, these modern improved breeds may struggle in the harsh African climate compared with indigenous breeds (Fig. 2) which may possess less production potential but are better acclimated to the weather conditions and a limited plane of nutrition.

Figure 2: *Indigenous chicks ready for delivery.*

Livestock also are indirectly affected through climate change impacts on the quantity and quality of farm-produced fodder and grazed feed resources (Descheemaeker et al., 2018), changes in pest and disease resistance and changes in the availability and quality of water resources (Descheemaeker et al., 2025). In addition, compared with farmers in industrialized countries, African smallholders have poor access to information and knowledge from Extension services and other outlets on weather, prices, and agronomic and livestock management. This hinders making timely decisions and adapting farm management practices to changing weather conditions.

Furthermore, a lack of Extension officers (exacerbated by vast areas of operation per officer), lack of/inadequate means of transportation, limited road networks and infrastructure, poor availability to Extension/outreach services and limited access to credit, assistance and insurance preclude the investment in modern agricultural inputs and adaptive farm management that could cushion farmers against climate change (Descheemaeker et al., 2025). Smallholder farmers have few preventative and curative strategies at their disposal to cope with climate variability and change (Wichern et al., 2023). Moreover, some strategies increase households' vulnerability. For example, common practices like selling assets (e.g., livestock) or eating less in response to a market shock have a strong impact on income and food security, which is felt over prolonged periods and bear the risk of forcing households into a poverty situation (Descheemaeker et al., 2025).

Food security is a critical global challenge and a key factor in achieving zero hunger, number two on the list of the 17 UN Sustainable Development Goals (SDGs) (UN, 2024). It has four pillars—availability, accessibility, utilization, and stability—and they are all affected by food safety. Therefore, food security and food safety are interrelated concepts. In 2024, approximately 783 million people, one in ten globally, remained in chronic hunger (WHO, 2024). This highlights the urgent need to develop sustainable food systems that ensure food security and safety while minimizing resource depletion and maximizing economic and social welfare (Story et al., 2009). To achieve sustainability in the food sector, environmental efficiency (maximizing output and benefits received by societies while minimizing negative environmental impacts) is needed (Knight and Rosa, 2011). Unfortunately, efficiency varies across countries due to numerous factors such as economic policy uncertainty, institutional quality and political orientations (Barra and Falcone, 2023, 2024a).

The circular bioeconomy has emerged as a promising strategy to enhance sustainability in the food sector (Barra and Falcone, 2024b). The circular bioeconomy offers sustainable solutions that conserve resources, improve food production processes and create new food products from biobased materials and waste (Wu et al., 2023). Given its potential to expand food choices, increase social wellbeing and reduce environmental footprints, the circular bioeconomy plays a critical role in fostering a sustainable food system, thereby supporting SDG2 (Zero Hunger) (Ahmad and Ashraf, 2023). A sustainable food system, in theory, should ensure affordable, safe food access for all while balancing economic, social and environmental factors, including resource conservation and stakeholder welfare (Rocha, 2008; Story et al., 2009; Sustainable Development Commission, 2009).

African Union frameworks such as Agenda 2063, the Science, Technology and Innovation Strategy for Africa (STISA-2024), and the African Continental Free Trade Area (AfCFTA) create the political space to mainstream bioeconomy initiatives. Aligning these frameworks with national strategies in countries such as South Africa, Ethiopia and Kenya ensures that the bioeconomy becomes not just an academic concept but an engine of development (BioInnovate Africa, 2022; AUDA-NEPAD, 2023).

Circular bioeconomy models in Africa have the potential to reshape economic, social and environmental landscapes. Economically, they create new value chains by transforming agricultural and forestry residues into biofertilizers, bioplastics and energy products, boosting small and medium enterprises (SMEs) while enhancing competitiveness in regional and global markets (Virgin et al., 2022). Socially, these models improve livelihoods by creating employment opportunities, especially for women and youth, while providing more affordable and nutritious food options that contribute to household resilience (Doss et al., 2018). Environmentally, circular practices promote regenerative agriculture, reduce waste and support biodiversity conservation, thereby lowering GHG emissions and building resilience to climate change (FAO, 2019a; Trisos et al., 2022).

Challenges

Policy makers across Africa, Eastern Africa in particular, are confronted with the urgent need to generate economic growth, create new jobs, provide opportunities for women and youth and increase agricultural productivity, all while dealing with rapid population growth (Virgin et al., 2022). Add to this, mounting pressure to protect the environment and fragile ecosystems and to ensure resilience in the face of emerging threats such as climate change and diseases. From a global perspective, the promotion of a circular bioeconomy is high on the political and business agenda for many countries as a major strategic driver for the transformation of biobased sectors for sustainable economic growth and development (Virgin et al., 2022). However, despite its potential, integrating circular bioeconomy principles into food systems presents several challenges.

For example, Holden et al. (2023) highlights that current research on the circular bioeconomy's role in food system sustainability remains fragmented. Existing studies primarily focus on technical, chemical and biological processes for producing biobased products from biowastes without addressing the role of such approaches in an integrated sustainable food system (e.g., Daza-Serna et al., 2013; Albizzati et al., 2021; Ahmad and Ashraf, 2023; Anagnostopoulou et al., 2024). There are studies exploring the literature on food waste and circular bioeconomy but without investigating mechanisms through which the circular bioeconomy enhances food system sustainability (Nguyen et al., 2025).

A central feature of the circular bioeconomy is that scientific research knowledge and innovation can be applied not only to produce food, feed, fiber and fuel but also to produce a wide range of agro-industrial and value-added products (Virgin et al., 2022). Another critical cornerstone of the bioeconomy is to increase value around local bioresources, eliminate waste and maximize and use all parts of primary produce and their products. More than 65 percent of the population of Eastern Africa depends on biological resources for food, energy, medicine and other uses (Virgin et al., 2022). They frequently use these biological resources in their raw form and dispose of significant quantities as biological waste. As a result, there is huge potential to add value to these biological resources through the development of the circular bioeconomy.Food systems encompass all the elements (environment, infrastructure, institutions, people) and activities (farming, transportation, packaging, marketing) that relate to the production, processing, distribution, preparation, and consumption of food (and associated waste management), and the outputs of these activities leading to socio-economic and environmental outcomes (Ingram and Thornton, 2022). African food systems face significant challenges that are linked to the continent's development (Dorvlo et al., 2025). More than half of the population live in poverty and one in five people in Africa face food insecurity (WHO, 2024). Widespread degradation of the natural resource base (Chikanda, 2009), compounded by climate change impacts, are considered drivers of declining productivity and resilience (IPBES, 2018).

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Food systems are integral to the achievement of many of the UN's 17 SDGs. Historically, however, global food systems research has focused on industrialized food systems, with less attention given to Africa and other differently structured systems in which pre-existing ways of production, distribution and consumption were reshaped by colonialism and post-independence structural adjustment (McMichael, 2013). Much of the research in Africa has focused specifically on agricultural production rather than the entire food system (FAO, 2020a, b). The lack of reliable and complete data (Béné et al., 2019) has made it difficult to build a robust and evidence-based understanding of African food systems across diverse regions and cultures (Ingram, 2011).

As a result, a framework for food systems analysis in Africa is needed to guide analysis and promote transformation while ensuring equitable opportunities for vulnerable communities amidst diverse cultural contexts (May et al., 2025). The Food Systems Research Network for Africa (FSNet-Africa) project developed a tailored analytical framework aimed at enabling holistic African food systems analysis. The framework (Fig. 3) comprises three interconnected aspects—food systems drivers, the food system itself and food system outcomes. The aspects and their respective components are connected by feedback and feed-forward loops that mitigate or amplify changes to conserve or disrupt the system's resilience (May et al., 2025).

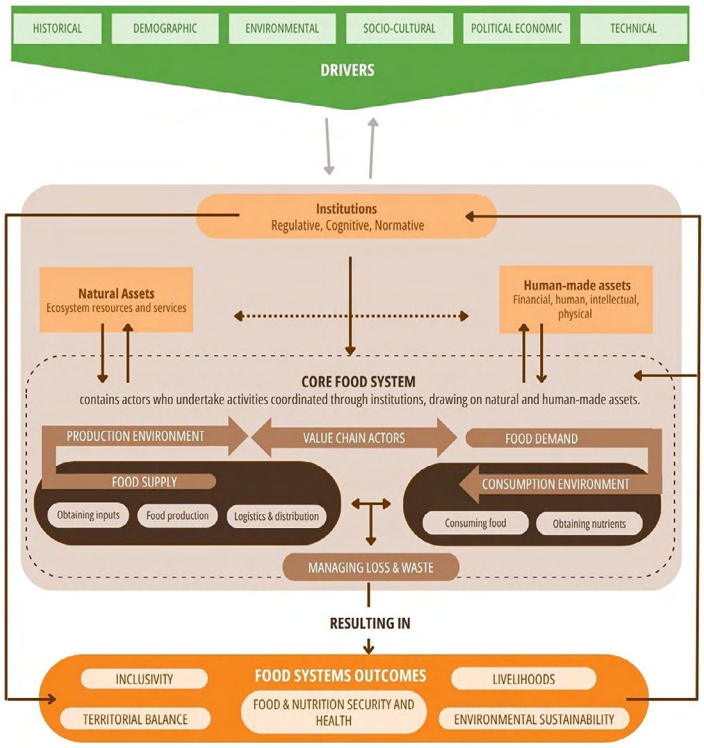

Figure 3: *The FSNet-Africa food systems framework. Source: May et al., 2025.*

In reality, there is no single African food system. With more than 2,000 languages, 3,000 ethnic groups, 54 countries and 10 major agro-ecological zones, the continent contains a diversity of food cultures and food environments (Shoup, 2011; Duru, 2020; FAO et al., 2024). African food systems have characteristics that distinguish them from industrialized systems. They have been shaped by the legacy of colonization in ways that continue to distinguish them from those of other more industrialized world regions, creating spatially uneven agrarian structures and enduring inequalities in access to land (Cooper, 2019). Furthermore, across the continent, land and livestock are not only economic assets but also serve as crucial elements of identity, social status and cultural heritage (Zeleza, 1994; Chigbu, 2013; Guyer, 2019).

Women and youth are central to the functioning of African food systems, yet they face structural constraints that inhibit their full and equitable participation (May et al., 2025). Women contribute disproportionately to food production, processing, marketing and household nutrition, yet are routinely excluded from decision-making, land ownership, credit access and Extension services (Doss et al., 2018). In addition, with 60 percent of the continent's population under the age of 25, Africa has a demographic advantage that could be harnessed for agricultural innovation and food system transformation (Ahmed et al., 2016; Rocca and Schultes, 2020). However, young people often struggle to enter agricultural value chains due to a lack of access to land, finances and market infrastructure as well as perceptions that farming is unprofitable or socially undesirable as a career path (Mkandawire et al., 2021).

Despite its promise and potential, bioeconomy adoption in Africa is constrained by several structural challenges. Policy fragmentation remains a persistent barrier, as ministries responsible for agriculture, environment, energy and trade often pursue disconnected agendas (Ncube et al., 2022). Financing remains inadequate, with SMEs and smallholder farmers facing difficulties in accessing credit, insurance or blended finance models that could de-risk investments (Salvador et al., 2022). Weak Extension services and low levels of mechanization limit the dissemination of bioeconomy innovations (Diao et al., 2020). Moreover, gender and youth inequities persist, as women continue to face restrictions on land ownership, market access and decision-making while young people often lack the capital and institutional support to engage in agricultural value chains (Mkandawire et al., 2021; Rocca and Schultes, 2020). Technology adoption also lags, as African agricultural systems remain dependent on human labor and simple tools, limiting competitiveness in a global market driven by digital and biotechnological solutions (Nguyen et al., 2025).

Possibilities

Indigenous crops and African foods are increasingly recognized for their pivotal role in preserving cultural traditions and identities, promoting improved livelihoods and nutrition, and achieving sustainable and climate-resilient agriculture (Akinola et al., 2020). FSNet-Africa research projects (Mwila et al., 2023; Boakye et al., 2024; John et al., 2024; Lungu, 2024; Vilakazi, 2024) have investigated how these crops can strengthen a community's control over their food systems and act as drivers for African food system transformation (Dorvlo et al., 2025). However, perception barriers exist where many view traditional crops as "food for the poor" (John et al., 2024). As such, the accessibility and acceptability of indigenous crops and African foods requires a raising of awareness concerning their nutritional value and advocacy to preserve traditional food systems.

A food system includes a set of activities from production to consumption, comprising comprehensive upstream and downstream relationships (Ericksen, 2008). Among these, upstream linkages involve activities related to production, processing, packaging, marketing and distribution, whereas downstream flows include consumption and disposal and treatment of wastes (Nguyen et al., 2025). In a traditional linear economy, these activities follow a one-way trajectory, moving from upstream to downstream. However, in a circular bioeconomy, resource flows are bidirectional, creating closed-loop operations that minimize waste and optimize resource efficiency (Ericksen, 2008; Ahmad and Ashraf, 2023).

The sustainability of a food system is driven by multiple environmental, economic and social factors (Fig. 4) (Nguyen et al., 2025). A circular food system aims to minimize waste to a sub-zero level and effectively address environmental, social and economic challenges (Cusenza et al., 2021; Chitaka and Schenck, 2022). This approach enhances food security and safety while promoting environmental, social and economic welfare of all involved stakeholders.

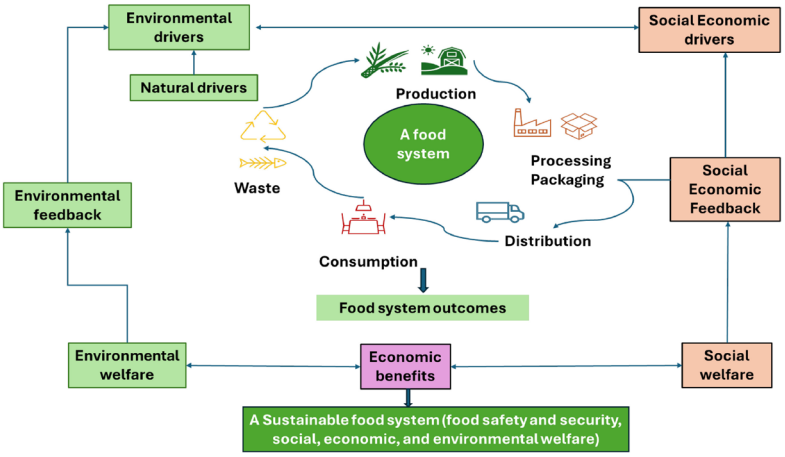

Figure 4: *A food system and its drivers and feedback pathways. (Drawn based on Ericksen, 2008 and Sustainable Development Commission, 2009). Source: Nguyen et al., 2025.*

A circular bioeconomy supports food security and food safety, which are critical to sustainable food systems (Lang and Barling, 2012) through four key mechanisms: 1) creating innovative food products from bioresources to expand dietary options (new food product generation); 2) extending the longevity of food post-harvest or post processed, ensuring sustained availability (product life extension); 3) improving food safety and shelf life through sustainable packaging solutions (sustainable packing); and 4) enhancing crop yields by using green manure and maintaining productivity while reducing pesticide use. Food safety presents particular challenges in African food systems given the predominance of informal supply chains and local markets governed by weak or non-existent regulations (Aworh, 2021). A lack of knowledge and awareness limits the ability of consumers to demand safer food and for consumer awareness to act as a lever for food safety (Dorvlo et al., 2025).

Food loss also is a daunting challenge, but opportunities exist. Most food loss in the region happens between harvest and the point of sale. Very little food is wasted by consumers after it is purchased. Some of the primary causes of food loss are a lack of cold chain facilities (especially for perishable items), unreliable and inadequate storage facilities and insufficient processing skills among smallholder farming communities. On-farm losses of fruits and vegetables are up to 50 percent, the highest in the world (FAO, 2019b). However, biological control of insect pests offers one promising opportunity to reduce production and post-harvest losses (Virgin et al., 2022), while opportunities related to the use of edible films and coatings can help preserve sensory qualities such as taste, aroma and appearance; prevent oxidative rancidity in meat products; delay ripening in fruits and vegetables; maintain pigments in food products; and extend shelf life (Ulusoy et al., 2018)

Africa has fallen behind many other parts of the world in the use of technology and innovation in agriculture. Smallholder farmers still mostly rely on human power and simple tools in agricultural production, resulting in low and stagnant crop yields (Diao et al., 2020). The FSNet-Africa case studies mentioned earlier collectively underscore the urgent need for appropriate innovation and technological solutions for smallholders that are more inclusive and climate-smart and can improve crop and livestock production value chains, advance environmental sustainability and improve livelihoods.

Additional FSNet-Africa case studies (Anim-Jnr et al., 2023; Isingizwe et al., 2023; Cheboi et al., 2024; Izdori, 2024; Kwapong et al., 2024a, Kwapong et al., 2024b) investigated how to minimize food loss and waste and maximize resource efficiency across the food value chain and revealed that circular economy principles, appropriate technologies and multi-stakeholder collaboration were central themes in achieving these goals. Reducing food loss, particularly at production, post-harvest and in distribution, is a critical priority for African food systems. A circular bioeconomy approach is becoming increasingly important to achieve sustainable food systems. It is still a relatively new concept that creates new value chains and reduces waste compared to a linear economy (Kirchherr et al., 2017). A circular bioeconomy is based on using resources more efficiently and enhancing sustainability with minimal effects on the environment.

Several mechanisms exist through which circular bioeconomy practices can support sustainable food practices (Fig. 5). The current literature primarily focuses on **availability** (improving yields, extending food life), and **adequacy** (food safety). However, other aspects of food security, including **accessibility** (physical and economic access to food), **acceptability** (cultural suitability and acceptance of food) and **agency** (role of politics and regulations in place to foster food security and safety) (Rocha, 2008) have been underexplored. A circular bioeconomy improves food security by optimizing resource use through cascading bioresources and valorizing biowastes. This approach creates new food products, extends shelf life, and improves crop yields, ensuring greater food availability without additional land use (Nguyen et al., 2025). In line with the perspective of environmental efficiency (Knight and Rosa, 2011), a circular bioeconomy maximizes outputs and benefits received by society while minimizing environmental inputs (land, water, energy) and reducing environmental footprints.

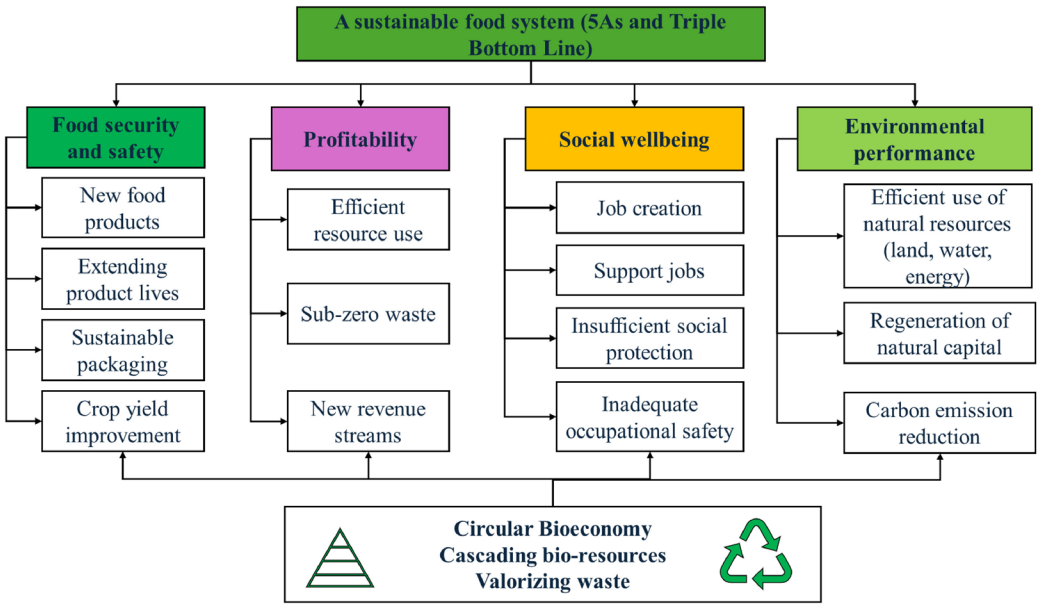

Figure 5: *A summary of the mechanisms offered by the circular bioeconomy for sustainable food production. Source: Nguyen et al., 2025.*

However, a circular bioeconomy requires a change in how things are done, and change comes with costs and, sometimes, resistance. Despite potential benefits of the circular bioeconomy in terms of profitability, it is not surprising that the transition to a circular bioeconomy involves higher upfront investment costs, and lack of financial resources hinders implementation and remains a prominent barrier (Salvador et al., 2022). In addition, biobased products often struggle with price competitiveness against traditional, linear economy products (Salvador et al., 2022). Beyond financial concerns, adopting a circular business model requires organizational restructuring, supply chain reconfiguration and technological investment (Ncube et al., 2022). Therefore, further research should explore the long-term financial viability of circular bioeconomy-based food production and examine business models that balance profitability with sustainability.

Growth of the circular bioeconomy in support of sustainable food systems offers an opportunity for countries across Africa to achieve many of the UN Sustainable Development Goals by 2030, making use of the region's abundant natural resources, including under-utilized agricultural waste materials, to produce value added products with applications across multiple sectors including food, health, energy, and industrial goods, thereby creating jobs, generating wealth, and connecting smallholder farmers to new biobased value chains. The development of a modern circular bioeconomy across the African continent will assist in making the following outcomes a reality (Virgin et al., 2022):

- Sustainable industrialization, job creation and green growth, revitalizing bioprocessing and biomass value chains in the region and promoting circular bioeconomy production systems with reduced emissions through productive and efficient use of biowaste.
- Improved food security through enhanced value chains and processing, promoting a more secure and resilient food supply while contributing to sustainable, healthy, affordable and nutritious food for the growing population in the region.
- Improved health, using biodiversity in the region to develop cost effective biobased production systems for various biopharmaceutical products that address specific health challenges in the region (HIV, malaria and non-communicable diseases, etc.).
- The creation of new biobased products, including biomaterials for construction, bio-inputs for agriculture, enzymes for industry and biobased feedstocks (e.g., biofertilizers, bio-packaging) to substitute products derived from petrochemicals and to satisfy growing demands from consumers (e.g., functional foods, special dietary needs, novel health and well-being products).
- Linking farmers and bioentrepreneurs to local, national, regional and international market opportunities. New biobased value-added products that are attractive on the world market can assist the private sector in Africa to expand and improve its global competitiveness and stimulate sustainable economic growth.
- Creating new forms of clean sustainable modern bioenergy, such as biofuels, for transportation and electricity generation from biowaste and industrial byproducts, mitigating climate change and massive use of wood fuel that leads to deforestation.
- Protecting the environment through converting waste, which today threatens ecosystems and freshwater resources, to useful products.

Development of modern circular bioeconomies across Africa, particularly Eastern Africa, has the potential to transform primary production in agriculture, the backbone of most economies in the region, but also in sectors like aquaculture, forestry, health and industry. The region is endowed with vast bioresources, including abundant plant and animal genetic resources (many of which remain underexplored and unutilized), arable land and agricultural residues, forestry resources and marine and freshwater resources that can support a vibrant sustainable bioeconomy. There are excellent opportunities in the region to develop businesses that efficiently and sustainably add value to primary produce; invest in the production of biobased novel food, feed, fuel and health products; convert biowaste into usable products; and develop biomaterials with the potential to transform agriculture and other sectors (Virgin et al., 2022).

Success Stories, Progress, and Policy

Several emerging success stories illustrate Africa's vast bioeconomy potential. For example, in Kenya, women-led cooperatives have successfully transformed cassava waste into biofertilizers, demonstrating both gender empowerment and waste valorization (Cheboi et al., 2024). Ethiopia's national bioeconomy roadmap has positioned biotechnology and biobased innovation as cornerstones of its industrial strategy (Bio and Emerging Technology Institute, 2024). In South Africa, startups are leading in the production of biodegradable packaging derived from sugarcane, creating new market niches while addressing plastic pollution (Chitaka and Schenck, 2022). In Uganda, youth-driven digital platforms are connecting farmers to bio-input markets, showing how demographic advantages can be leveraged to accelerate innovation and market participation (Kwapong et al., 2024a). These cases highlight how grassroots and national-level strategies can work in synergy to drive Africa's bioeconomy forward.

For credibility and long-term sustainability, Africa's bioeconomy must be tracked through measurable indicators. These include contributions to GDP and employment, the value and volume of agricultural and forestry residues valorized, reductions in GHG emissions, the number of SMEs supported and levels of gender and youth participation in biobased sectors (Barra and Falcone, 2024a). Additional metrics should include the extent of restored ecosystems, improvements in food safety and nutrition and the number of inclusive policies implemented. Transparent and consistent measurement frameworks will not only strengthen policymaking but also attract domestic and international investors.

To advance the African bioeconomy, regional frameworks should be harmonized under African Union and AfCFTA structures to create economies of scale and foster market integration. Financing mechanisms must be strengthened through blended finance models, impact funds and insurance schemes that de-risk investments for SMEs and smallholders. Women and youth must be at

the center of bioeconomy strategies, supported by gender-responsive credit schemes, land access reforms and targeted capacity-building programs. Investment in digital innovation, particularly AI, the Internet of Things and blockchain, should be prioritized to modernize value chains and improve resilience. Indigenous crops and food systems should be promoted through awareness campaigns, research funding and value-addition initiatives that shift perceptions and enhance cultural acceptance. African universities, think tanks and research institutes require dedicated funding to strengthen bioeconomy research and innovation ecosystems. Finally, public-private partnerships should be fostered to connect bioentrepreneurs with incubators, markets and international investors, enabling Africa to integrate into global biobased value chains.

Summary

Africa has been ignored as a potential food powerhouse for far too long. However, addressing Africa's food security and nutrition targets will require a comprehensive and inclusive approach that integrates the diverse perspectives and needs of all stakeholders. By fostering collaboration, understanding political and power dynamics and addressing food loss and waste through best practices, it is possible to develop transformative solutions that combat hunger and empower communities. Promoting indigenous knowledge, local innovations and underutilized crops and livestock is essential for building resilient and sustainable food systems. Engaging smallholders at the local level in decision-making ensures that interventions are relevant and practical, paving the way for a sustainable and food-secure future by 2030 and beyond. Transforming from linear to circular bioeconomies across Africa has much potential for individual countries and the continent as a whole. There will be impacts from the transformations, and challenges that must be addressed. However, with the right plan and the right people in place, the possibilities appear to be endless.

Africa is positioned to be a global bioeconomy leader by leveraging its abundant biomass, youthful population and growing regional integration. However, the transformation from linear to circular food systems necessitates the collective efforts of all stakeholders, including farmers, producers, processors, retailers and consumers. In addition, transitioning from a linear to a circular bioeconomy will require political commitment, financial innovation, inclusive governance and technological advancement. By addressing systemic challenges and capitalizing on emerging opportunities, Africa can build resilient food systems, drive sustainable industrialization and deliver on the SDGs. The possibilities and opportunities are vast, and with deliberate action, the African bioeconomy can power a greener and more inclusive future.

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